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Influence of different temperature regimes and water stress on yield components and qualitative characteristics of oil seed in canola (*Brassica napus* L.)

[1]Amir Hossein Shirani Rad, [1]Ali Khorgami, [2]Shahram Rashidi*, [2]Sharareh Nasr Esfahani, [2]Fatemeh Barekati and [2]Vahideh Namvar vahid

[1]Department of Agronomy, Khoramabad Branch, Islamic Azad University, Khoramabad, Iran
[2]Department of Agronomy, Science and Research Branch, Islamic Azad University, Tehran, Iran

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ABSTRACT

In order to study of water stress effect on quantitative and qualitative traits of rapeseed in temperature regimes, an experimental was carried out as a factorial on RCBD with three replications in two years (2012 and 2013).Soil experimental located in Karaj region. Treatments were included planting date factor with six levels consisted of 22 June and 2, 12, 22 July and 1, 11August. Irrigation factor with three levels, normal irrigation and stress was started from flowering and stress was started from pod formation. The main effects of planting date and irrigation on traits of stem diameter and height was statistically significant in level of 1%. However the interactive effect of planting date and irrigation on the mentioned traits was significant in level of 5%. ANOVA for the interactive effects shown RGS003 planted on June 22nd with normal irrigation had the most pods number per plant (81.5) and grain number per pod (19.9). RGS003 planted on June 22nd with normal irrigation had the most yield of grain oil with an average of 1124 kg/ha and RGS003 planted on August 11th with the drought stress started from flowering had the least yield of grain oil with an average of 218 kg/ha. It was also found based on ANOVA for the interactive effects of planting date and irrigation on the total chlorophyll content that the most chlorophyll content was attributed to RGS003 planted June 22nd and normal irrigation with an average of 1.914 mg/g wet weight. The most glucosinolate content was also attributed to RGS003 planted August 11th with the drought stress started from flowering with an average of 29.27 mg/g dry weight. Otherwise RGS003 in the 11August and stress in flowering had the highest erusic acid (1.839%), and in the 22 June and common irrigation had the lowest erusic acid (0.2807%).

Keywords: water stress, Canola, Oil yield, Glucosinolate, Erucic acid

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INTRODUCTION

Oilseeds after cereal are noteworthy as the second important source of human energy in the world. Therefor in order to secure the needed oil, necessity in planning to attain self-sufficiency production of edible oil in developing countries is undeniable. In the recent years regarding to emphasis on the sustainable agriculture and crop rotation, researchers has been focused on canola as an appropriate crop, which can be in rotation with winter cereals. Environmental stress such as drought, thermal (heat and cold), flooding, salinity, nutrient, and soil acidity strongly decline plant growth and subsequently yield in comparison to standard condition (Bray et al., 2000)[1]. Depending on type and intensity of stress, this reduction in crop yield potential changes in a range of 54% to 82%. Among all environmental stress, the drought stress as the most important limiting factor in the plant growth and crop yield threaten a range of 40% to 60% the total agricultural land in the world (Bray et al., 2000; Shao et al., 2004)[1, 12]. Drought enormously damages crops and horticultural products in the word, especially in Iran, every year. Drought stress influences on plant growth in the all stages of plant life. However, the amount and severity of damage, capacity of compensation and its effects on yield are depending on the stage of plant life in stress (Farooq et al., 2008)[4]. According many researches it was found out that the drought stress influences on growth, photosynthesis, breathing and aging plant.

In Iran, decreasing the available water per capita caused by population growth, climate change, excessive utilization and reduced quality of water resources has caused a significant increase of the drought damage. The available water per capita has noticeably dropped from 7000 m^3 in 1950 to 1900 m^3 in the recent years 2000. Taking into consideration the strong population growth it is expected that the available water per capita in Iran with a decreasing trend will approach to 1300 m3 up to 2025 (Keshavarz and Sadeghzadesh, 1999)[8]. In order to achieve an optimum yield in arid and semi-arid like Iran, using the new methods of irrigation is suggested to overcome water scarcity. Using the new technologies can significantly enhance water use efficiency and prevent accumulation of salts in the root growth zone resulting in a yield increment. In view of the fact that occurrence of drought stress is often coincident with the stages of flowering and pod formation (filling grain) of canola in the most agricultural areas of Iran, the present study has focused on the investigation of the drought stress effects on quantitative and qualitative traits as well as grain yield.

MATERIALS AND METHODS

In order to investigate the effect of drought stress on quantitative and qualitative traits of canola at the diverse temperatures, the research was carried out based on factorial treatments in a randomized complete block design with three replications and two years (2012 and 2013) in Karaj, Iran. The planting date was considered in six levels including June 22nd, July 2nd, 12th, 22nd and August 1st and 11th and the drought stress was considered in three levels including normal irrigation (control), discontinuing irrigation from the flowering stage and from pod formation stage. Each experimental plot was including 6 lines with length of 6 m. The distance of between lines and bushes on each line were considered to be 30 cm and 5 cm respectively. Two line sides were considered as marginal lines then only four middle lines were used to determine all phonological stages of plant as well as divers traits such as plant height, stem diameter, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, 1,000 Seed weight (g), grain yield, harvest index, oil yield, total chlorophyll content, glucosinolate content and percent of erucic acid. After two years, the combined analysis of characteristics and comparison of means based on Duncan's multiple range tests was performed at the five percent level. The statistical analysis was performed using MSTATC software.

RESULTS AND DISCUSSION

Plant height and stem diameter: The simple effects of planting date and irrigation on plant height were significant at the one percent level and the interaction effects of these factors were significant at the five percent level (Table 1). Comparison of means test relate to the interactive effect between planting date and irrigation on the plant height shown that RGS003 planted on June 22nd and normal irrigation had the highest plant height with an average of 111.8 cm and RGS003 planted on August 11th with discontinuing irrigation from the flowering stage had the shortest plant height with an average of 36.9 cm (Table 2). The simple effects of planting date and irrigation on stem diameter were significant at the one percent level, but the interaction between planting date and irrigation on yield were significant at the five percent level (Table 1). Comparison of means test relate to the interactive effect between planting date and irrigation on the stem diameter shown that RGS003 planted on June 22nd and normal irrigation had the thickest stem diameter with an average of 10.9 mm and RGS003 planted on August 11th with discontinuing irrigation from the flowering stage had the least stem diameter with an average of 4.3 mm (Table 2).

The number of branches per plant: The simple effects of planting date and irrigation on the number of branches per plant were significant at the one percent level and the interaction effects of these factors were significant at the five percent level (Table 1). Comparison of means test relate to the interactive effect between planting date and irrigation on the number of branches per plant shown that RGS003 planted on June 22nd and normal irrigation had the most number of branches per plant with an average of 6 branches and RGS003 planted on August 11th with discontinuing irrigation from the flowering stage had the least number of branches per plant with an average of 2.2 branches (Table 2). Decreasing the number of branches in the stress condition could be attributed to decreasing the number of subshrub in plant which is because of decreasing instigate and production of initial causer of branch as well as decreasing transfer nutrient to the initial branches. The stress condition caused morphological and developmental changes in plant like inhibition of branch growth and increase of root growth.

Table1. The results of combined analysis of variance in studied characters

SOV	df	Plant height (cm)	Stem diameter(cm)	Branches per plant
Year(Y)	1	235.669 **	10.391 **	4.813 **
Error	4	258.499	1.676	0.482
Planting Date(PD)	5	6127.937 **	37.837 **	17.328 **
Y*PD	5	19.645 ns	0.054 ns	0.043
Irrigation(I)	2	8523.843 **	84.22 **	19.684 **
Y*I	2	27.265 ns	0.125 ns	0.054 ns
PD*I	10	68.51 *	0.927 *	0.998 *
Y*PD*I	10	0.094 ns	0.001 ns	0.001 ns
Error	68	50.237	0.867	0.647
Total	107	-	-	-
CV%	-	8.59	11.56	19.64

**, ** and ns: significantat5%, 1% probability levels, and Non-significant.*

Table2. Mean comparison of interaction effect for Planting Date and Irrigation

Planting Date	Irrigation	Plant height (cm)	Stem diameter (cm)	Branches per plant
22 June	normal irrigation(Control)	111.8 a	10.9 a	6 a
22 June	water stress started from flowering stage	87.6 cde	8.6 def	4.8 b-e
22 June	water stress started from pod formation stage	107.3 a	10.3 ab	5.5 ab
2 July	normal irrigation(Control)	107.6 a	10.5 ab	5.6 ab
2 July	water stress started from flowering stage	81 ef	8 e-h	4.1 def
2 July	water stress started from pod formation stage	103.1 ab	9.9 abc	5.1 a-d
12 July	normal irrigation(Control)	104.8 a	9.6 bcd	5.2 abc
12 July	water stress started from flowering stage	75.1 fg	6.5 ij	3.5 fgh
12 July	water stress started from pod formation stage	96.1 bc	8.6 def	4.3 c-f
22 July	normal irrigation(Control)	92.9 cd	8.9 cde	4.7 b-e
22 July	water stress started from flowering stage	62.8 hi	5.7 jk	3 ghi
22 July	water stress started from pod formation stage	86.4 de	8.1 efg	3.8 efg
1 August	normal irrigation(Control)	84.5 de	8.2 efg	4.1 def
1 August	water stress started from flowering stage	48.2 j	5 kl	2.5 hi
1 August	water stress started from pod formation stage	74.9 fg	7.4 ghi	3.3 fgh
11 August	normal irrigation(Control)	67 gh	7.6 f-i	3.4 fgh
11 August	water stress started from flowering stage	36.9 k	4.3 l	2.2 i
11August	water stress started from pod formation stage	57.5 i	6.9hi	2.9 ghi

Means in each column having similar letter (s), are not significantly at the 5% level.

The number of pods per plant: The simple effects of planting date and irrigation on the number of pods per plant were significant at the one percent level and the interaction effects of these factors were significant at the five percent level (Table 3). Comparison of means test relate to the interactive effect between planting date and irrigation on the number of pods per plant shown that RGS003 planted on June 22nd and normal irrigation had the most number of pods per plant with an average of 81.5 pods and RGS003 planted on August 11th with discontinuing irrigation from the flowering stage had the least number of pods per plant with an average of 30.2 pods (Table 4). As a result, the treatments, which has a favorable condition of moisture, soil as well as the effective factors above surface soil (environmental condition, genotype), growth in a better condition resulting in a more number of pods in the main stem. Regarding to the straight relationship between the number of pods per plant and the number of subshrub in plant, with increasing the number of subshrub in plant, the number of pods increased that conformed with research results reported by Singh and Saxena (1991)[14].

Pod length: The simple effects of planting date and irrigation on the pod length were significant at the one percent level and the interaction effects of these factors were significant at the five percent level (Table 3). Comparison of means test relate to the interactive effect between planting date and irrigation on the pod length shown that RGS003 planted on June 22nd and normal irrigation had the longest pod length with an average of 6 cm and RGS003 planted on August 11th with discontinuing irrigation from the flowering stage had the shortest pod length with an average of 1.9 cm (Table 4). Reduction in the pod length in stress condition was attributed to decreasing water and minerals absorption by plant and subsequently decreasing production and transfer nutrients to grain. In addition, the stress caused to decrease pure photosynthesis resulting in a decrease the relative growth rate.

Number of seeds per pod: The simple effects of planting date and irrigation on the number of seeds per pod were significant at the one percent level and the interaction effects of these factors were significant at the five percent level (Table 3). Comparison of means test relate to the interactive effect between planting date and irrigation on the number of seeds per pod shown that RGS003 planted on June 22nd and normal irrigation had the most number of seeds per pod with an average of 19.9 seeds and RGS003 planted on August 11th with discontinuing irrigation from the flowering stage had the least number of seeds per pod with an average of 7 seeds (Table 4). Decreasing the number of seeds per pod was attributed to the reduced number of pods per branch and plant as well as the reduced pod length and pod formation in stress conditions. Most damage is caused by stress on falling flowers. The results shown the number of seeds per pod is an important effective characteristic on yield of canola. Based on the results of performed research, the number of seeds per pod was found to be the most positive effective factor on yield that was in agreement with the reports of Chavan et al. (1990), Hashem et al. (1998), Miller et al. (2003) and Sinaki et al. (2007) [2, 5, 10, 13].

Table3. Table1. The results of combined analysis of variance in studied characters

SOV	df	Pod number per plant	Pod length (cm)	Seeds number per pod
Year(Y)	1	1516.501 **	1.541 ns	20.716 **
Error	4	14.041	0.832	8.661
Planting Date(PD)	5	2418.418 **	14.771 **	134.837 **
Y*PD	5	10.272 ns	0.011 ns	0.113 ns
Irrigation(I)	2	4433.504 **	30.364 **	350.985 **
Y*I	2	18.779 ns	0.028 ns	0.294 ns
PD*I	10	30.836 *	0.529 *	1.505 *
Y*PD*I	10	0.084 ns	0.001 ns	0.001 ns
Error	68	24.522	0.424	1.179
Total	107	-	-	-
CV%	-	8.64	16	7.25

**, ** and ns: significantat5%, 1% probability levels, and Non-significant.*

Table4. Mean comparison of interaction effect for Planting Date and Irrigation

Planting Date	Irrigation	Pod number per plant	Pod length (cm)	Seed number per pod
22 June	normal irrigation(Control)	81.5 a	6 a	19.9 a
22 June	water stress started from flowering stage	62.7 ef	4.3 def	15.1 fg
22 June	water stress started from pod formation stage	70.4 cd	5.3 abc	19.4 ab
2 July	normal irrigation(Control)	76.7 ab	5.7 ab	19.5 ab
2 July	water stress started from flowering stage	56.5 fg	3.8 fg	14.3 fg
2 July	water stress started from pod formation stage	67 de	4.9 bcd	18.7 ab
12 July	normal irrigation(Control)	73.5 bc	5.3 abc	18.2 bc
12 July	water stress started from flowering stage	47.4 hi	3.4 ghi	12.7 h
12 July	water stress started from pod formation stage	62.7 ef	4.6 cde	16.7 de
22 July	normal irrigation(Control)	65.8 de	4.8 cde	17.3 cd
22 July	water stress started from flowering stage	42.4 ij	2.8ij	10.9 i
22 July	water stress started from pod formation stage	57.6 fg	4 efg	15.6 ef
1 August	normal irrigation(Control)	61.2 ef	4.2 d-g	15.7 ef
1 August	water stress started from flowering stage	38 j	2.4 jk	8.8 j
1 August	water stress started from pod formation stage	47.9 hi	3.5 f-i	14 g
11 August	normal irrigation(Control)	51.6 gh	3.6 fgh	14.1 g
11 August	water stress started from flowering stage	30.2 k	1.9 k	7 k
11August	water stress started from pod formation stage	38.9 j	2.9 hij	12 hi

Means in each column having similar letter (s), are not significantly at the 5% level.

1,000 seed weight: The simple effects of planting date and irrigation on 1,000 seed weight were significant at the one percent level and the interaction effects of these factors were significant at the five percent level (Table 5). Comparison of means test relate to the interactive effect between planting date and irrigation on 1,000 seed weight shown that RGS003 planted on June 22nd and normal irrigation had the most 1,000 seed weight with an average of 3.87 g and RGS003 planted on August 11th with discontinuing irrigation from the flowering stage had the least 1,000 seed weight with an average of 1.67 g (Table 6). Grain weight affect by two factors of grain filling rate and duration. Drought stress during the grain filling period may reduce grain filling rate or duration as a result grain weight decreases. Drought stress at the flowering stage can cause a decrease in 1,000 seed weight by reducing the supply of assimilates. Conducted a study to investigate the effects of temperature and moisture stress and reported the average weight of the grain depended on the duration of grain growth as well as the number of seeds per plant. They also reported the grain weight decreased in both high and low temperatures. The mentioned results in the present study were in agreement with Mendham and Salisbury, (1995) and Vyas et al. (2001) [9, 15].

Oil yield: The simple effects of planting date and irrigation on the oil yield were significant at the one percent level and the interaction effects of these factors were significant at the five percent level (Table 5). Comparison of means test relate to the interactive effect between planting date and irrigation on the oil yield shown that RGS003 planted on June 22nd and normal irrigation had the most oil yield with an average of 1124 kg/ha and RGS003 planted on August 11th with discontinuing irrigation from the flowering stage had the least oil yield with an average of 218 kg/ha (Table 6). Drought stress and high temperatures reduce the polyunsaturated fatty acids in canola oil and have a negative effect on the oil content. However irrigation can improve the stress conditions. Increasing the amount of water and decreasing the stress rate enhance the oil content of grain. It seems that the drought stress does not significantly influence on the grain quality, but the drought stress in the flowing stress can noticeably decline the oil content of grain. Kajdi (1994) investigated the changes of oil content as well as the relation between the oil and protein contents for 21 varieties with and without irrigation [7]. They reported the mean grain and oil yield related to the treatment with irrigation was higher than the treatment without irrigation. The mention results confirmed the results of researches performed by Diepenbrock (2000), Jensen et al. (1996), Mendham and Salisbury (1995), Rao and Mendham (1991) and Sinaki et al. (2007)[3, 6, 9, 11, 13].

Total chlorophyll content: Both the simple and interaction effects of planting date and irrigation on the total chlorophyll content were significant at the one percent level (Table 5). Comparison of means test relate to the interactive effect between planting date and irrigation on the total chlorophyll content shown that RGS003 planted on June 22nd and normal irrigation had the most the total chlorophyll content with an average of 1.914 mg/g wet weight and RGS003 planted on August 11th with discontinuing irrigation from the silique formation stage had the least the total chlorophyll content with an average of 0.972 mg/g wet weight (Table 6).

Table5. Table1. The results of combined analysis of variance in studied characters

SOV	df	1000 Seed weight(g)	oil yield (kg.ha-1)	Total chlorophyll ($mg.g^{-1}$ fw)
Year(Y)	1	2.001^{*}	244150.231^{**}	0.016^{ns}
Error	4	0.962	1984.315	0.001
Planting Date(PD)	5	6.138^{**}	906502.654^{**}	0.715^{**}
Y*PD	5	0.012^{ns}	5248.343^{ns}	0.001^{ns}
Irrigation(I)	2	3.124^{**}	1067885.731^{**}	1.036^{**}
Y*I	2	0.004^{ns}	6206.231^{ns}	0.001^{ns}
PD*I	10	0.514^{*}	9581.665^{*}	0.084^{**}
Y*PD*I	10	0.001^{ns}	43.609^{ns}	0.001^{ns}
Error	68	0.338	8455.08	0.015
Total	107	-	-	-
CV%	-	18.77	14.73	8.77

**, ** and ^{ns}: significantat5%, 1% probability levels, and Non-significant.*

Table6. Mean comparison of interaction effect for Planting Date and Irrigation

Planting Date	Irrigation	1000 Seed weight(g)	Oil yield ($kg.ha^{-1}$)	Total chlorophyll ($mg.g^{-1}$ fw)
22 June	normal irrigation(Control)	3.87 a	1124 a	1.914 a
22 June	water stress started from flowering stage	3.57 abc	747 cd	1.451 de
22 June	water stress started from pod formation stage	3.65 abc	969 b	1.671 bc
2 July	normal irrigation(Control)	3.77 ab	992 b	1.791 ab
2 July	water stress started from flowering stage	3.33 a-e	551 ef	1.338 ef
2 July	water stress started from pod formation stage	3.57 abc	809 cd	1.601 cd
12 July	normal irrigation(Control)	3.65 abc	854 c	1.693 bc
12 July	water stress started from flowering stage	3.23 a-e	492 ef	1.232 fg
12 July	water stress started from pod formation stage	3.45 a-d	701 d	1.472de
22 July	normal irrigation(Control)	3.47 a-d	709 d	1.562 cd
22 July	water stress started from flowering stage	2.73 def	370 gh	1.202 fg
22 July	water stress started from pod formation stage	2.93 c-f	583 e	1.399
1 August	normal irrigation(Control)	3.02b-f	583 e	1.447 de
1 August	water stress started from flowering stage	2.32 fg	281 hi	1.248 fg
1 August	water stress started from pod formation stage	2.62 ef	448 fg	1.096 gh
11 August	normal irrigation(Control)	2.62 ef	453 fg	1.238 fg
11 August	water stress started from flowering stage	1.67 g	218 i	1.204 fg
11August	water stress started from pod formation stage	2.3 fg	358 gh	0.972 h

Means in each column having similar letter (s), are not significantly at the 5% level.

Glucosinolate and erucic acid content: The simple effects of planting date and irrigation on the oil yield were significant at the one percent level and the interaction effects of these factors were significant at the five percent level (Table 7). Comparison of means test relate to the interactive effect between planting date and irrigation on the glucosinolate content shown that RGS003 planted on August 11th with discontinuing irrigation from the flowering stage had the most the glucosinolate content with an average of 29.27 mg/g meal dry weight and RGS003 planted on June 22nd and the normal irrigation had the least the glucosinolate content with an average of 15.17 mg/g meal dry weight (Table 8). Both the simple and interaction effects of planting date and irrigation on the erucic acid content were significant at the one percent level (Table 7). Comparison of means test relate to the interactive effect between planting date and irrigation on the erucic acid content shown that RGS003 planted on June 22^{nd} and normal irrigation had the least erucic acid content with an average of 0.2807 and RGS003 planted on August 11th with discontinuing irrigation from the pod formation stage had the most erucic acid content with an average of 1.839 (Table 8).

Table7. Table1. The results of combined analysis of variance in studied characters

SOV	df	Glucosinolate content ($mg.g^{-1}$ dw)	Erucic acid (%)
Year(Y)	1	10.286 ns	0.044 *
Error	4	0.056	0.032
Planting Date(PD)	5	192.55 **	1.402 **
Y*PD	5	0.036 ns	0.001 ns
Irrigation(I)	2	211.625 **	4.038 **
Y*I	2	0.06 ns	0.003 ns
PD*I	10	4.467 *	0.117 **
Y*PD*I	10	0.001 ns	0.001 ns
Error	68	2.95	0.007
Total	107	-	-
CV%	-	8.41	10.96

**, ** and ns: significantat5%, 1% probability levels, and Non-significant.*

Table8. Mean comparison of interaction effect for Planting Date and Irrigation

Planting Date	Irrigation	Glucosinolate content ($mg.g^{-1}$ dw)	Erucic acid (%)
22 June	normal irrigation(Control)	15.17 j	0.2807 n
22 June	water stress started from flowering stage	18.62 gh	0.6298 hij
22 June	water stress started from pod formation stage	16.05 ij	0.4024 m
2 July	normal irrigation(Control)	15.85 ij	0.3779 m
2 July	water stress started from flowering stage	19.98 fg	0.864 e
2 July	water stress started from pod formation stage	17.45hi	0.5098 kl
12 July	normal irrigation(Control)	17.25 hij	0.4542 lm
12 July	water stress started from flowering stage	21.47 c-f	0.9674 d
12 July	water stress started from pod formation stage	18.92 gh	0.6071 ijk
22 July	normal irrigation(Control)	18.62 gh	0.5703 jk
22 July	water stress started from flowering stage	23.53 bc	1.217 c
22 July	water stress started from pod formation stage	20.4gh d-g	0.7177 fgh
1 August	normal irrigation(Control)	20.2 efg	0.6753 ghi
1 August	water stress started from flowering stage	25.22 b	1.459 b
1 August	water stress started from pod formation stage	22.45 cd	0.8023 ef
11 August	normal irrigation(Control)	22.18 cde	0.7729 efg
11 August	water stress started from flowering stage	29.27 a	1.839 a
11August	water stress started from pod formation stage	24.93 b	1.003 d

Means in each column having similar letter (s), are not significantly at the 5% level.

CONCLUSION

The RGS003 planted on June 22nd and normal irrigation(control) had the highest number of pods per plant, Number of seeds per pod, 1,000 seed weight, oil yield and total chlorophyll content with averages of 81.5, 19.9, 3.87 (g), 1124 ($kg.h^{-1}$) and 1.914 ($mg.g^{-1}$ $_{fw}$) Respectively. The RGS003 planted on June 22nd and normal irrigation (control) also had the lowest erucic acid and glucosinolate content with averages 0.2807(%) and 15.17(mg.g-1 $_{DW}$) Respectively.

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